Improving Fishing Technology to Catch (or Conserve) More Fish: The Evolution of the ICES Fishing Technology and Fish Behaviour Working Group During the Past Century.[1]

By

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Abstract

Even at the beginning of this century, ICES was concerned about fishing technology especially the increasing use of trawls and the proportion of undersized fish in the catch. In 1904, the 2nd volume of the “Rapports et Proces Verbaux” includes an article titled ‘Draft program for experiments with nets (trawls) by request of the Bureau’. At that time, in response to a memorandum on the subject from Sweden, ICES formed a sub-committee to investigate comparative fishing of several types of trawls. This sub-committee later evolved into the North Sea Sub-Committee on Comparative Fishing. In 1954, after an informal meeting at The Hague between scientists from The Netherlands, Lowestoft, Aberdeen, and Hamburg, a petition was drawn up to recommend to the Bureau the creation of a full committee to deal with investigations into fishing gears and fishing methodology. This committee was formed in 1955 and became known as the Comparative Fishing Committee.

During the 1950s and 1960s technological advances in underwater photography, acoustics and trawl-mounted instrumentation provided the first means to study fishing gear in scientific detail. The consequent increase in studies of fishing gear and fish behaviour led in 1967, to the establishment of the Gear and Behaviour Committee. It was not until 1973 that long-term specific Working Groups were established under the Gear and Behaviour Committee: 1) Working Group on Research and Engineering Aspects of Fishing Gear, Vessels and Equipment and 2) Working Group on Reaction of Fish to Fishing Operations. These two groups were combined in 1983 to form the present Working Group on Fishing Technology and Fish Behaviour (WGFTFB). The evolution of the activities of this Working Group throughout the history of ICES, whether carried out in earlier times by committees, subcommittees, study groups or short-term working groups, closely parallels that of the fishing industry and has played an important role in contributing to the development and implementation of theoretical and applied fisheries science.

Keywords: behaviour, fish, fishing, ICES, selectivity, surveys, trawls,

Introduction

The evolution of the Working Group on Fishing Technology and Fish Behaviour (WGFTFB) in ICES closely parallels that of the fishing industry and strong links between science and the industry have resulted. Prior to its official creation in 1983, the Working Group existed in many forms throughout the history of ICES, with its work being carried out by a number of committees, working groups, and study

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groups. The Working Group has altered the emphasis of its work over the years as the priorities of the fishing industry, and the scientific and ICES community have developed. Key topics in the past 50 years included the study of new trawl designs and methods to increase the fishing power of vessels to catch more fish, the development of fuel efficient operation during times of high oil prices, and the study of 'conservative' gears focusing on increasing the efficiency and selectivity of both mobile and static fishing gears for finfish. In recent years, the focus of research has been on conservation of the resource with most research directed towards bycatch reduction in the fishery, impacts of fishing gears on the ecosystem, and the catchability of both mobile and static fishing gears used as sampling tools in estimating stock size.

The ability of the Working Group to make a significant contribution has been governed to a great extent by technical advances in methods of studying fishing gear. The gradual development of underwater instrumentation for measuring the performance of fishing gear since the 1950s and the sudden appearance in the 1970s of lowlight underwater television to observe gears and particularly fish reaction to them has created great opportunities for scientists. Through research on fish behaviour and fishing gears used in commercial harvesting and resource surveys, the evolution of this Working Group has played an important role in contributing to the development and implementation of theoretical and applied fisheries science.

This paper will present a historical account of the evolution of the Working Group on Fishing Technology and Fish Behaviour and synthesize the major developments in fish capture as they relate to the science of conservation, harvesting and stock assessment during the past century of ICES. Although much of the work on the technical aspects of fishing were carried out by a number of committees, working groups and study groups since the inception of ICES, this historical synopsis begins in the 1940s.

1945 - 1960

In the late 1940s and the 1950s, there were major advances in technology of great importance to both the fishing industry and fishing technology research. Echosounders and netsondes were developed for use on vessels and fishing gear, underwater photography was pioneered providing a vital tool for fish behaviour studies, underwater instrumentation for the study of the engineering performance of fishing gears was developing, and synthetic materials for netting became available on the market. These technical advances generated a new dynamism in research and development. There was a gradual recognition that the fish capture process could now be studied as a scientific discipline and fishing gear design might not be so much a 'black art', but more a science (von Brandt, 1954). The FAO sponsored International Fishing Gear Congress held in 1957 in Hamburg reflected this new attitude.

"... we stand at the threshold of a new era where systematic gear research will be increasingly fruitful........" H Kristjonsson, (Introduction in Anon, 1959).

There was also a realism regarding the need for significant funds to be concentrated in national centres:

"If rapid progress is to be made then Governments must set up and/or support gear research institutes." D.B.Finn (Preface in Anon, 1959).

The new impetus can perhaps be traced back to the Special Scientific Meeting organised by ICES in 1948 on 'The comparative efficiency of fishing craft, their gear and modifications to gear' (ICES, 1949). In the conclusions and recommendations, Wimpenny first proposed studies on the reaction of fish to trawls and, as well, a range of experiments to assess the factors affecting trawl catch. The North Sea Sub-committee on Comparative Fishing was the vehicle for these discussions within ICES. In 1954, however, at an informal meeting in The Hague between experts from the Netherlands, Germany, England, and Scotland it was agreed to propose to ICES the elevation of this sub-committee to full Committee status (von Brandt, 1954). The ICES Committee on Comparative Fishing was duly formed in 1955. One of the interesting features of the Committee was the excellent mix of expertise of the members, with stock assessment biologists, gear technologists, statisticians, behaviourists, and instrumentation engineers all making important contributions.

The measurement of gear performance (summarily drag, speed and spread and more fully heights, depths, angles, and distances) became possible with the development of underwater self-recording instruments (de Boer, 1954). The consequent full-scale data provided the first means to validate the mathematical descriptions of fishing gear which had been evolving e.g., in Japan and Russia (reviewed by Steele, 1955). The technique of physical modeling gear performance was also introduced (Dickson in Anon, 1959), stemming from the original work by Tauti (1934) in Japan. Photographic equipment for observation of fish reaction and gear behaviour complemented the engineering instrumentation. Television and cine film, as well as still photographs, of trawls and seines in action were taken in the early 1950s (Sand, 1959; Ben-Yami, 1959; Craig and Priestley, 1960). At this stage, divers were the principal means to deploy such equipment, which restricted the depth at which it could be used. The introduction of acoustic equipment such the echosounder to locate fish and the netsonde to identify net position relative to fish schools was a catalyst for the development of pelagic fisheries, particularly in Germany. These instruments and the subsequent development of efficient midwater trawl doors greatly increased the catching potential of commercial operations, but also provided a means to determine pelagic trawl gear performance and hence develop improved gears. Fisheries management was also affected as it opened up new opportunities for assessing pelagic fish stocks (Parrish, 1953). Such developments in pelagic gears and acoustic instrumentation continued throughout the 1960s and 1970s. Fernandes et al. (2001) provide a major review of the development of acoustics within ICES.

The key area of research study during the 1950s was selectivity of fishing gears - mainly of mobile gears, but also of set nets and traps. The difference in selectivity of codends made of natural and new synthetic materials was studied exhaustively, as was the relation with mesh size. The selectivity of a range of species was investigated including haddock, cod, redfish, whiting, dab, plaice, herring, lobsters, and crabs. This prolific period of work was driven by international collaboration with major selectivity exercises being undertaken in the North Sea and the Arctic. The Comparative Fishing Committee formed short-term working groups in the late 1950s and early 1960s, such as the ICES Mesh Selection Working Group, to provide a forum to maintain momentum and co-ordinate this work. Much of this work was also presented at a 1957 joint ICNAF/ICES/FAO scientific meeting in Lisbon (Anon, 1963).

By 1955, the techniques for measurement of mesh size were under careful scrutiny and the need for a standard method was recognised (Boerema, 1958). The importance of assessing the differing characteristics of new and traditional twines and netting was also understood both for its influence on selectivity and on the more practical concerns of fishermen. The work of Klust, von Brandt and others within ICES culminated in the important reference book on netting materials (Klust, 1973). It is interesting to note that this subject was revived within ICES during the 1990s.

1961-1970

Under the guidance of the Comparative Fishing Committee, several short-term working groups were set up during the decade to deal with specific issues such as mesh selection in commercial gears, selectivity analysis, effect of fishing vessel characteristics on effort measurements, and fishing gear and fish behaviour (See Appendix I). Commercial gear development research was directed towards creating more efficient trawling and improving fish and shellfish selection. Great strides were made in the development of pelagic and semi-pelagic trawls and high-opening bottom trawls in different countries. The Lowestoft and Aberdeen Laboratories tested bottom trawls of different design and rigging to estimate their effect on catchability of roundfish in many comparative fishing experiments involving both research vessels and commercial trawlers. As a result of this activity, many studies of the engineering and hydrodynamic performance of trawls and the development of new instrumentation for trawl monitoring took place (MacLennan, 1970). At the same time in Canada, similar work by Carrothers et al. (1969) was taking place. The first model experiments on fishing gears using the flume tank in Boulogne-sur-Mer took place in 1960 (Portier, 1968). As a consequence, theoretical studies of gear performance were balanced by many papers on practical gear design and operation directly relevant to commercial fisheries. Later, the towing tanks and flume tank would become important experimental tools for gear research. Much of this early research was presented at the second FAO Fishing Gear Congress held in the United Kingdom in 1963 (Anon, 1964).

With the continuous developments in underwater instrumentation, many fish behaviour studies centered on improving fishing gear efficiency and improving the mesh selection process. At the 1963 FAO Congress, early experiments describing fish reactions to various components of fishing gears at different light levels were presented by Blaxter et al. (1964) which set the stage for a proliferation of fish reactions to fishing gear behavioural studies for the next two decades. In addition, there was also a proliferation of tank and field studies directed at such topics as fish attraction by light, the effect of netting of different colours, the reactions to noises emitted by vessels and echo sounders, which included investigating the hearing threshold of cod, led by the UK and Norway. Diurnal variations in distribution and schooling behaviour of several species were studied through echogram analysis (ICES, 1963). As the decade progressed, new observation techniques (frogmen, underwater photography, film and TV, towed vehicles, echo sounder transducers mounted on the gear, electronic sector-scanning equipment) significantly increased our knowledge of fish behaviour and fishing gear performance. A prime example was the development of the Nephrops and shrimp trawls in which fish and shellfish species could be separated from each other (Kurc and Betus, 1969). Much of this fish behaviour research was presented at the FAO Conference on Fish Behaviour in Relation to Fishing Techniques and Tactics held in Bergen, Norway in 1967 (Olsen, 1968; Ben-Tuvia and Dickson, 1968).

In the 1960s, synthetic netting yarns had almost completely replaced the yarns made of natural fibers for the construction of fishing nets. Further mesh selection experiments comparing the two groups of materials were carried out. Closely related to the selectivity work was the acceptance of the Westhoff gauge (Westhoff, 1961), renamed the ICES gauge at the 1961 ICES Annual Meeting (ICES, 1962; Westhoff et al. 1962) as the standard mesh gauge for research work. The results obtained with the new gauge were frequently compared with those of the ICNAF gauge and the wedge gauge used by fisheries inspectors (Parrish and Pope, 1964). In the early 1960s the Technical Committee ISO/TC 38 "Textiles" of the International Organization for Standardization (ISO) started drafting standards on fishing nets. Gear specialists initiated and collaborated in drafting standards on definitions, numbering systems, cutting rates, methods for testing of netting materials, drawings of fishing nets etc (von Brandt, 1963). However, a consensus of opinion was never reached on the draft proposal "Method of test for the determination of size of opening of mesh". It was not until the late 1990s that this topic would again have prominence.

Selectivity research again dominated much of the activities in the Comparative Fishing Committee. In 1962, the Icelandic Trawl Selection Working Group was created which oversaw a milestone in selectivity research, the creation of the International Selectivity Experiment in Icelandic Waters in 1962 in which Germany, Iceland, the UK, the USSR, Norway and Canada took part (Anon, 1965). More international collaboration continued under the 1969 ICES/ICNAF Joint Working Group on Selectivity Analysis whose task was "to investigate further all factors (including physical properties of net twines and biological factors) which cause, or may cause, differences in mesh selection" (Anon, 1969). The current state of methodology used in these selectivity studies received much attention with two major reviews being published based on research over the past decade (Holden, 1971; Pope et al., 1975). Although mesh selection studies were prominent throughout the decade, attention was also paid to the influence of hook and bait characteristics on the selectivity of longlines. In the early 1960s, the first research into species selective trawls began in France and the Netherlands with studies of shrimp and fish separating trawls. By the end of the decade, research was also being done in Norway and Iceland.

Due to the proliferation of fishing gear and behavioural studies, the Gear and Behaviour Committee was formed in 1967 to oversee developments in this area. Soon after in 1970, a new Working Group on Gear and Behaviour Methodology was established to "review research methods and techniques" and "to assess the priorities of study in gear and behaviour research" (ICES, 1970).

1971-1980

The decade was characterized by the so-called energy crises because of the wars in the Middle East, which led to a sharp increase in oil prices. At the same time, safety and working conditions aboard fishing vessels became an issue when gear fasteners in beam trawling caused vessels to capsize with associated loss of life. Many technical research studies in The Netherlands and Belgium began to address these issues in the 1960s and 1970s. In 1972, The Gear and Behaviour Committee recommended the creation of a new Working Group on Research on Engineering Aspects of Fishing Gear, Vessel and Equipment to handle the diversity of this research (ICES, 1972). During the rest of the decade, the Working Group considered many topics such as automated fish grading devices and fish transportation, purse seine handling onboard, working conditions and safety, onboard mechanization of longlining, energy consumption and fuel saving, gear and pipeline interactions, wheelhouse layout, vessel simulation models, onboard processing, vessel underwater noise, and interactions of vessels and gears.

The oil crisis called for research into ways and means to decrease fuel consumption for fishing fleets, especially reducing the hydrodynamic drag of towed fishing gears. New studies of gear geometry and drag measurements included trawl model studies in flume tanks (see for example, Wileman, 1976), and direct observations using manned (Main and Sangster, 1981) and unmanned towed vehicles on research vessels. The results were then tested aboard chartered commercial fishing boats. Due to the proliferation of studies on measuring the engineering performance of fishing gears, a code of practice for the conduct of these experiments was developed by McLennan, (1980). In midwater trawls, several new designs were investigated such as: rope trawls (De Boer, 1978, 1979 1980), trawls with large hexagonal meshes (Jakupsstovu, 1979 and Isaksen et al., 1979), and trawls with large rhombic meshes (Brabant and Portier, 1978). The latter two types were found to be superior and are still in use today. Efforts to reduce the drag of beam trawls used in the North Sea flatfish fishery revived an interest in using electric stimulation to replace the tickler chains. This research work was started in the late 1960s and early 1970s in The Netherlands (De Groot and Boonstra, 1974), Scotland (Stewart, 1975), Germany (Horn, 1976) and Belgium (Vanden Broucke, 1973). The first applications in fishing gears were tested in shrimp beam trawls and later in trawls for catching flatfish (particularly sole). Testing and redesigning of the electrical equipment followed throughout the decade and into the next, right up to 1988. Electrical stimulation was successful and it was widely anticipated that it would be introduced into commercial practice, but it never happened (van Marlen et al., 1997). Ironically, the general outcry to diminish the impact of fishing gears on benthic substrate and benthos refocused interest in electrical stimulation in 1995, and new experiments started in The Netherlands and Belgium.

Although fish behaviour studies were recognized as an integral part of fishing gear research for gear technologists, it was also acknowledged that such studies could be a beneficial tool for stock assessment biologists to understand and interpret some of the fluctuations in abundance indices. Bringing the two groups closer together could achieve common goals. A formal step in that direction came with the 1972 ICES recommendation to establish a new Working Group on Reaction of Fish to Fishing Operations (ICES, 1972) under the Gear and Behaviour Committee. Research into the relationship between sound/vibrations and fish capture continued in the early 1970s. By 1973, a description of standard techniques for making sound measurements was accepted within the Committee (ICES, 1974). Fish physiology studies (swimming performance and reactions to fishing gears) were being carried out at the Aberdeen laboratory (Wardle, 1976). About the same time, the methodology to study fish behaviour in large aquarium tanks was being developed (Wardle and Anthony, 1973). Field studies of fish behaviour reactions to towed gear benefited from the further development of scuba diving and television techniques.

During the 1970s, the effect of twine thickness on codend selectivity became more prominent in the debate. The Gear and Behaviour Committee had initially concluded that there was no discernible effect on selectivity between light and heavy twines (ICES, 1971), however, by the end of the decade, new research had proven that heavy twines adversely affected selectivity (ICES, 1981). Meanwhile, the focus on developing species-selective trawls continued in the Nephrops fishery. At the 1973 Gear and Behaviour Committee meeting, the discussion of selective shrimp trawling was prominent and the Committee concluded that "…. such fishing gears and devices can help to reduce the wastage of by-catch" (ICES, 1974). More and more the emphasis within ICES was shifting towards improving fishing technology to not only reduce the catches of small fish, but also to reduce the wastage of non-target species. The Committee "agreed that member countries should be asked to pay closer attention to the development of fishing gears and equipment to safeguard the by-catch". Again in the 1974 annual report of the Gear and Behaviour Committee, "the importance of preventing unwanted by-catch from coming into a trawl was again stressed, and also the importance of returning the unwanted by-catch from the deck to sea in the best possible condition" (ICES, 1975). These views still have relevance to present-day fisheries. From the mid to late 1970s research within the ICES member countries focused on factors other than mesh size, which may affect codend selection such as weight of catch, trawling speed, and netting material and construction. By the end of the decade two very successful species-selective technical devices had been introduced through legislation: turtle excluder device (TED) used in shrimp fisheries in the USA (Watson and Seidel, 1980) and the "Nordmøre Grid" used in the Barents Sea shrimp fisheries to reduce catches of finfishes (Isaksen et al., 1990).

In 1978, the Gear and Behaviour Committee name was changed to the Fishing Technology Committee and one year later, in 1979, it was again renamed the Fish Capture Committee (see Appendix I).

1981-1990

At the 1983 ICES Statutory Meeting, the Consultative Committee endorsed the recommendation of the Fish Capture Committee to combine the Working Groups on 1) Research on Engineering Aspects of Fishing Gear, Vessel and Equipment and 2) Reaction of Fish to Fishing Operations into one group called the Working Group on Fishing Technology and Fish Behaviour. Because of the proliferation of developments into acoustic instrumentation and ensuing studies, a second group was established and named the Fisheries Acoustic Science and Technology Working Group. Both working groups would hold joint sessions throughout the 1980s and 1990s to discuss common issues of fish behaviour and sampling gear selectivity.

During this decade, work continued on energy consumption and potential for energy conservation in the fishing industry (see for example Thorsteinsson, 1984; van Marlen, 1985). Many of these investigations into energy-conservative fishing methods involved full-scale instrumented sea trials and scale models tested in flume tanks. In 1981, the Engineering Working Group noted that problems encountered correlating the results from engineering studies of full-scale trawls versus scale model experiments could only be resolved if a standard technique for the measurement of twine diameter was adopted. This initiated the establishment of the Study Group on Twine Thickness Measurement in 1982, which developed a recommended procedure for measuring twine thickness (Ferro, 1983). The Working Group on Reactions of Fish to Fishing Operations began to address other low-energy fishing methods (Anon, 1981). A stream of contributions followed dealing with such subjects as new hook designs, different sizes and types of bait, effects on gillnet efficiency of different hanging ratios, mesh sizes, and twine types, the effects of water flow on the performance of gillnets and the distribution of olfactory stimuli from baited gears (see for example Stewart, 1986; Bjordal, 1987; Løkkeborg, 1987). At the 1983 joint session meeting of the Engineering and Fish Reaction Working Groups, members acknowledged that the common practice of using high-priced fish as bait could seriously handicap the development of longline fisheries due to bait shortages resulting from increased direct human consumption and the poor status of most of the bait-fish stocks (Anon, 1983). As a result of the need to develop effective low-cost baits, a 2-year ad hoc Working Group on Artificial Bait and Bait Attraction was established in 1984 to evaluate why artificial baits had not been as successful to date as natural baits (Anon, 1984, 1985).

The development of species- and size-selective commercial fishing methods continued to have high priority in the 1980s. Focusing on the reactions of various species to gear components, behaviour studies were carried out in laboratory settings and by means of divers and increasingly through the use of video camera-equipped remotely controlled vehicles to observe actual responses in situ (Priestley et al., 1985). The need to reduce the high mortality of juvenile whiting and haddock in the North Sea trawl fisheries in the early 1980s led to studies of square mesh codend designs. Observations of square-mesh codends by Scottish and Norwegian researchers showed that the meshes were fully open along their entire length and that they retained fewer small fish than diamond mesh cod-ends of the same mesh size (Isaksen and Valdemarsen, 1986; Robertson and Stewart, 1988). Direct observations by Scottish researchers in the 1980s documented behavioural differences between Nephrops and fish when entering a trawl, and between different whitefish species. These observations inspired extensive experiments in the middle and late 1980s evaluating the use of horizontal separator panels to separate Nephrops from fish or to segregate different whitefish species within the trawl while fishing (see for example Main and Sangster, 1985; Valdemarsen et al., 1985).

Sampling and survey gear research became a major issue in the Working Group meetings. Population abundance indices from resource surveys were increasingly being used to calibrate fishery-dependent models and in many cases surveys were the only available source for stock size estimates. This called for more precise and detailed knowledge of the capture process of sampling gears. Concerns that differences in rigging of the ICES standard young fish trawl employed by the vessels participating in the International Young Fish Survey might lead to differences in catching efficiency (Galbraith, 1982) initiated a special topic at the 1984 inaugural meeting of the Working Group on Fishing Technology and Fish Behaviour. Several contributions noted that sampling trawl performance could be quite variable in ways that could increase the variance of abundance estimates based on area-swept techniques (Rush and Ferro, 1984; Wileman 1984; West, 1984). This initiated work to standardize sampling trawls, rigging, and operational procedures.

Access to commercially available hydroacoustic trawl instrumentation packages designed to measure trawl geometry in the mid-1980s was an important development in monitoring and reducing variability in trawl performance as well as detecting trawl malfunctions during survey operations (Galbraith, 1986, Hagstrøm, 1987). Employing these and other means, extensive studies in the mid- and late 1980's were conducted to quantify both bottom and pelagic sampling trawl efficiency and selectivity. These identified several factors such as the escapement of young fish beneath the groundgear, the effects of varying sweep lengths, and the influence of natural behaviour and responses to the vessel and/or trawl in the trawling zone (Ona and Chruickshank, 1986; Dickson, 1988; Engås and Godø, 1989a, 1989b; Walsh, 1989). Such studies resulted in recommended changes in gear design to increase the efficiency of sampling trawls in several ICES countries in late 1980s and early 1990s. The need among the ICES countries for more detailed and consistent specifications of survey gears and the increasing use of computer-aided design techniques in gear design led to the establishment of the ICES Study Group on Net Drawing. This Study Group played an important part in setting agreed standards for specifying nets (Anon, 1989).

1991- 1999

As the 1990s began, the International Baltic Sea Fishery Commission turned to ICES for advice on the use of square mesh codends in the Baltic. After careful review and a detailed report entitled 'A critical review of gear construction that improve size selectivity' (Anon, 1991), the Working Group was unable to offer conclusive findings on the use of square mesh in fishing gears. Today, square mesh codends are only in use on a voluntary basis in the Norwegian-Danish seine fishery to get access to closed areas, in the inshore Iceland shrimp trawl fishery, and as an optional measure (130 mm square or 140 mm diamond) in the Atlantic Canada cod and haddock fisheries on the Scotian Shelf.

Other technical devices were investigated within ICES member countries, including using square mesh panels in various sections of the codend and/or extension piece in trawls used in the North Sea whitefish and Nephrops fisheries, horizontal exit windows in the Baltic Sea cod fisheries, and shortened lastridge ropes in trawls used in Norway, Canada, and the Faroe Islands (Anon, 1994, 1995). Two new methods were introduced in the estimation of selectivity in codends: a new hooped codend cover by Scottish researchers to minimize masking of the meshes by the traditional ICES cover (Robertson et al., 1995) and twin trawling by Danish researchers to improve measurements of selectivity (Madsen and Moth Poulsen, 1994). In 1992, the UK introduced legislation for compulsory fitting of square mesh panels in the top sections of codends in the Nephrops fishery. During the same period, work on the use of grids /grates in fishing gears was continuing, lead by Norway. Although the initial focus was on bycatch reduction in the shrimp fishery, grids were being experimentally tested in bottom trawls, midwater trawls, beam trawls, and seines to separate various species. In 1997, Sort-X and Sort-V sorting grids (Larsen and Isaksen, 1993; Isaksen et al., 1995) were legislated for use in the otter trawl fishery of the Barents Sea to reduce the bycatch of undersized groundfish. A Study Group on Grid (Grate) Sorting Systems in Trawls, Beam Trawls and Seine Nets was created in 1995 to detail progress and methodology (Anon, 1996a).

In order to advise on the best practice for selectivity studies in ICES countries, the Working Group created a Sub-Group on Selectivity Methods in 1992 whose task was to write a 'Manual of Methods of Measuring the Selectivity of Towed Fishing Gears'. This manual was released as an ICES Cooperative Research Report (Wileman et al., 1996). At the request of other ICES committees, the Working Group provided advice on appropriate mesh sizes for use in Baltic Sea cod fisheries to ACFM and the Baltic fish Committee in 1994 and 1995 and advice to ACFM on the selectivity in the Nephrops trawl fishery of the North Sea (Anon, 1995, 1996b). The Working Group then focused on how to use commercial fishing gear selectivity measurements in stock assessment and, in 1995, recommended that a Study Group be established to examine the use of selectivity measurements in stock assessment (Anon, 1998). This Study Group brought together gear technologists, statisticians, and biologists. The estimation of whole fleet selectivity and the incorporation of fish survival data into stock assessment were important issues to this Study Group. At its 1998 meeting, the Working Group noted that new developments in design and statistical modeling of selectivity of static gears such as gillnets, longlines, and baited pots, was increasing and a new procedural manual similar to the one developed for towed gears was needed. It recommended that a Study Group on Selectivity of Static Gears be formed to write a manual of methods for measuring and analyzing the selectivity of static gears (Anon, 1999a).

It has long been recognized that codend selectivity is most likely to be affected by the hydrodynamic, behavioural, and mechanical characteristics of netting and twine. The openings of individual meshes are dictated by the twine thickness, flexural rigidity, and elongation of twine (Ferro and O'Neill, 1994). The fishing industry has concerns over the subjectivity of current mesh measurement methods and the lack of a standardized gauge to be used by EU fisheries inspectors, enforcement personnel (EU wedge gauge), and scientists (ICES spring gauge). An EU-funded concerted action project reviewed this whole issue of methodology and gauges in 1996 (Fonteyne et al., 1998) and reported its progress to the Working Group in 1998 and 1999. At the 1999 Working Group meeting, members strongly recommended that scientists and inspection services should be using the same technique and gauge in measuring mesh opening and recommended that a Study Group on Mesh Measurement Methodology be created (Anon, 1999b).

Although the question whether fish survived after coming into contact with fishing gears and escaping capture had come up in the 1960s, it was not until the 1990s that this research received considerable attention. Led by research in Norway, Scotland, Finland, and the Faroe Islands, most of this work focused on escapement of whitefish, herring, shrimp, and Nephrops from codends of otter trawls, pelagic trawls, seines and eventually from static gears such as longlines (see Sangster, 1992 for a review). A Sub-Group on Survival Experiments was set up in 1992 to review these results and the methodology (Anon, 1993, 1994). Preliminary analysis showed some striking and unexpected results, for example, after escaping through the meshes of a codend, mortality was higher among juvenile gadoids than among older fish (Sangster, 1992) and there was 90% mortality in herring escaping through the meshes of pelagic trawls (Surronen et al., 1993). The Working Group felt that further concerted action was needed and recommended that a Study Group on Unaccounted Mortality in Fisheries be created in 1994 (Anon, 1997a). After a detailed review, the Study Group recognized that there was a lack of data on estimation of many of its nine unaccounted mortality components for a wide variety of fisheries and more research was required to fill in the gaps. However, the importance of unaccounted mortality to fisheries assessment biologists, managers, and industry became obvious when inclusion of the escapement mortality component into fishing mortality estimates was shown to alter the perception of the North Sea haddock stock (Anon, 1998).

The 1992 ICES Symposium on Fish Behaviour in Relation to Fishing Operations held in Bergen concluded that "catching efficiency and selectivity of commercial fishing gears or research sampling gears are real world manifestations of fish behaviour" (Olsen, 1993). It was the first such symposium since the 1967 FAO Conference on Fish Behaviour in Relation to Fishing Techniques and Tactics (Ben-Tuvia and Dickson, 1968). While the FAO conference focused mainly on the role fish behaviour can play in increasing harvesting efficiency, the ICES symposium had a more conservation approach to harvesting. It concluded that 'obtaining detailed fish behaviour knowledge was necessary to meet the needs of responsible fishing with regard to size and species selective gears, by-catch reduction and survival of non-target species' (Olsen, 1993). During earlier decades, many of the fish behaviour results were mostly qualitative and descriptive in nature, however, during the 1990s emerging technologies such as data storage tags, acoustic positioning tags, swimming flumes, mobile and stationary acoustic transducers and scanning lasers systems permited quantitative studies of both natural and sampling tool-induced fish and shellfish behaviour. Noteworthy was the research on fish behaviour using acoustic transponding tags (Bjordal et al., 1993; Godø et al., 1994) and electronic data storage tags (Arnold et al., 1997; Godø and Michaelsen, 1997) to monitor fish and shell fish movements, migrations, and reaction behaviour toward fishing gears.

In the 1990s, research continued to focus on the evaluation of sources of variation and bias in the performance and catchability of survey bottom trawls used in annual resource surveys for finfish and shellfish. This research was led by Norway, Canada, Scotland, Germany, and the United States. At the request of various ICES Committees for advice regarding survey gears used in the North Sea and the Baltic Sea, the Working Group detailed two reports. In 1992, the Working Group evaluated the sources of variability in the fishing power of the GOV trawl used in the International Bottom Trawl Surveys and suggested revisions to the current manual of operations (Anon, 1992). In 1995, the Working Group reviewed the problems and advise on the selection of a standard bottom trawl survey gear to match the variety of (8) survey vessel sizes, bottom types and geographic areas in the Baltic Sea (Anon, 1995; 1997b). The Working Group undertook a major review of the survey gear research of ICES member countries in 1997 at the Annual Science Conference Theme Session on 'The Catching Performance of Fishing Gears Used in Surveys' (Walsh, 1999). Based on this review, the Working Group concluded that most countries were now in a position to standardize survey operations to reduce variability and measurement error in trawl geometry and performance and bring these biases to an acceptable level. The next stage in this research would be to investigate integrating estimates of survey trawl performance and catchability estimates into analytical models used in stock assessment (Anon, 1997d; Somerton et al., 1999). A Study Group was proposed and this topic was absorbed by the Study Group on the Use of Selectivity and Effort Measurements in Stock Assessment (Anon, 1998).

Other activities over the past 50 years

Fishing effort measurements

The development of fisheries management techniques based on the exploitation of fish stocks required the development of the concepts of fishing power and effort (Beverton and Parrish, 1954; Gulland, 1956), an additional topic within the remit of the Comparative Fishing Committee in the late 1950s and early 1960s. As with selectivity, international collaboration was undertaken to achieve significant progress within a reasonable time scale (Bertelsen et al., 1958). The measurement of fishing effort was an important study topic throughout the 1960s. In 1961, the Comparative Fishing Committee recommended a Symposium on Measurement of Abundance of Fish Stocks in connection with the 1963 Annual Meeting (Gulland, 1965). In putting forward this recommendation, the Committee had in mind "*the fundamental importance of this subject to all aspects of the study of fishery dynamics, including the measurement of fishing effort,…*". The Committee further proposed "that among the topics given special attention would be the diurnal variation of fish catches and the causes thereof". The use of tonnage and horsepower as indices of relative fishing power were examined. In 1968, the Gear and Behaviour Committee recommended setting up a Working Group to Study the Characteristics of Fishing Vessels in Terms of their Effect on Fishing Effort Measurement. Characteristics of fishing vessels and the relationship with fishing effort were dealt by the Working Group on Fishing Vessel Characteristics in Relation to Fishing Power and reported in 1970 (ICES, 1970; Anon, 1970). One fundamental concept which remained on the agenda for years was the use of swept volume as a measurement of fishing effort (Treschev, 1971), however, because of its theorectical nature it was not accepted as a common approach.

Fishing gear impact studies

Research into the impact of fishing gears on the sea bed had an initial start in 1955, but it was not until the late 1960s and early 1970s that efforts increased. The 1970 ICES annual report dealt with studies on the effect of passage of trawls over the sea bed and the 1971 report gave penetration depths ranging from 10-20cm, which were corrected to more realistic values in 1972. Later, these corrected depths were corroborated in the 1990s, when new technologies emerged (side-scan sonar, RoxAnn, boxcorer sampling). Possible conflicts between the fishing industry and other users of the sea were reported in 1977 by the joint session between the Gear and Behaviour Committee and the Fisheries Improvement Committee on the Interactions between Fishing and Offshore Oil and Gas Activities (ICES, 1977). In some cases, a reduction of mutual effects of fishing gear and offshore equipment was obtained by simple constructional adaptions, e.g., rounded bars on beam trawl shoes saving underwater cables (De Groot, 1979). In the 1980s, there was some activity in impact study research. In response to a request from the Demersal Fish Committee (C.

Res.1987/2:7) concerning increasing fishing power of several types of bottom trawling gear and their possible effects on the sea bed, the ICES Study Group on the Effects of Bottom Trawling was created to produce a state-of-the-art report (Anon, 1988).

Impact studies regained full momentum during the 1990s (Lindeboom and De Groot, 1998; Kaiser and De Groot, 2000). In the 1996 re-organisation of all committees under ICES, the terms of reference for the 'new' Fisheries Technology Committee were expanded to include measuring the direct physical effects of fishing operations, while ecosystem effects were being handled by the Study Group on the Ecosystem Effects of Fishing (ICES, 1996c; p 106). At the 1999 meeting of the Fishing Technology and Fish Behaviour Working Group, the collaborative results of many countries on the physical impact on benthos and benthic substrates and methodology used in studying such impacts were presented. The Working Group made the observation *"that many studies have been done on impacts and the time may be ripe to shift research effort away from further description of impacts towards ways in which gear can be modified to reduce impact"* (Anon, 1999b). Polet's (1999) work using electric pulses as an alternative stimulation and reduced bottom contact in the beam trawl as a method to reduce by-catch of juvenile flatfish in beam trawler shrimp fisheries is a good example of doing just that (Anon, 1999b).

Future Prospects for the Working Group on Fishing Technology and Fish Behaviour- The Next Decade.

The importance of resource surveys in stock assessment is well known; however, there is a recognized need to move from relative to absolute abundance indices. Emerging technologies such as new acoustic and imaging techniques should be applied to the tracking, species identification, and sizing of fish at greater ranges than are possible with current optical systems. The next step is to determine how to directly incorporate fish behaviour, such as reaction to vessel and trawl noise, biological and environmental factors, and trawl performance data into the analytical modeling of stock assessment. These new imaging technologies and improved fish behaviour studies will also benefit the rational development of commercial fishing gears by measuring whole selectivity (not only codends), estimating the efficiency of technical devices for species or size selection in gears and also validating models of the capture process in these fishing gears. We need to determine how to incorporate experimental estimates of fishing gear selectivity data and survival data of fish encountering these gears directly into an estimation of total fishing mortality for use in the stock assessment process.

As knowledge of fish behaviour improves, both mobile and static commercial gears can be more finely tuned to target narrower ranges of fish size and species and reduce by-catch. Improved technical conservation measures for fishery management should result. However, new designs have to be simple so that they are accepted by industry and easily enforced. Closer collaboration between stock assessment biologists, enforcement agencies, gear technologists and the commercial fishing industry is needed to develop effective, enforceable, practical and acceptable technical measures to further the aims of responsible fishing initiatives. Only then will the success rate of having new technical devices introduce through legislation increased.

The activities of the Working Group range from discussions on current developments to hands-on analysis in support of advice. The Working Group needs to be pro-active in liasing with other science committees, working groups and study groups to advise them of technological developments related to their activities. For example the Working Group has had the appropriate expertise to help in assessing the impact of fishing gears on the seabed and benthos, develop new methodologies, and design environmentally friendly fishing gears, but this study topic was only recently added to the FTFB mandate in the 1996 re-organization of ICES committees. The future will be challenging!

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Appendix I

Chronology of Related Committees, Working Groups, Study Groups and Sub-Groups

Committee	**Chair**	**Country**	**Time**
Comparative Fishing Committee	A. Von Brandt	Germany	1955-58
	R. J. H. Beverton	United Kingdom	1959-63
	S. Olsen	Norway	1964-65
Gear and Behaviour Committee	S. Olsen	Norway	1966-67
	A. von Brandt	Germany	1968
	A.R. Margetts	United Kingdom	1969-71
	J.G. de Wit	Netherlands	1972-74
	P.J.G. Carrothers	Canada	1975-77
Fishing Technology Committee	G. Kurc	France	1978
Fish Capture Committee	G. Kurc	France	1979-1980
	E.J. de Boer	Netherlands	1981-83
	G. Thorsteinsson	Iceland	1984-86
	D.N. McLennan	United Kingdom	1987-89
	K. Olsen	Norway	1990-92
	R. Fonteyne	Belgium	1993-95
Fisheries Technology Committee	P.A.M. Stewart	United Kingdom	1996-98
	O.A. Misund	Norway	1999-2001

Working Groups	**Chair**	**Country**	**Time**
Mesh Selection Working Group	G. Sætersdal J.A. Pope	Norway United Kingdom	1959 1960
Icelandic Trawl Selection Working Group	Jón Jónsson	Iceland	1962-63
ICES/ICNAF Joint WG on Selectivity Analysis	A.I. Treschev	USSR	1969-1970
Working Group on Gear and Behaviour Methodology	A.R. Margetts	United Kingdom	1970-1971
Working Group on Data Collection	J. J. Foster	United Kingdom	1972-1977
	D. N. MacLennan	United Kingdom	1978
WG on Standardization of Scientific Methods for Comparing the Catching Performance of Different Fishing Gears	H. Bohl	Germany	1972-1974
	J. A. Pope	United Kingdom	1975
W.G on Research into Sound and Vibrations in relation to Fish Capture	K. Olsen	Norway	1972-1975
	A. D. Hawkins	United Kingdom	1976
W.G. on Technical Aspects of Electrical Fishing	G. Vanden Brouke	Belgium	1975
W.G. to Study the Characteristics of Fishing Vessels in Terms of their Effect on Fishing Effort Measurement	J.G. de Wit	Netherlands	1960-70
WG on Reaction of Fish to Fishing Operations	G. Kurc	France	1973
	C.C. Hemmings	United Kingdom	1974
	C. Wardle	United Kingdom	1975-83
WG on Research and Engineering Aspects of Fishing Gear, Vessel and Equipment	J.G de Wit	Netherlands	1972-1975
	E.J. de Boer	Netherlands	1976-1980

	S. Olsen	Norway	1981-82
	G. Thorsteinsson	Iceland	1983
Joint Meetings of the Fish Capture Committee's Working Groups	E.J. de Boer	Netherlands	1983
Ad Hoc Working Group on Artificial Bait and Bait Attraction	Åsmund Bjordal	Norway	1984-85
Fishing Technology and Fish Behaviour	D. N. MacLennan	United Kingdom	1984-86
	B. van Marlen	Netherlands	1987-93
	S.J. Walsh	Canada	1994-97
	A. Engas	Norway	1998-2000

Study Groups/Sub-Groups	**Chair**	**Country**	**Time**
Study Group on Twine Thickness Measurement	R.S.T. Ferro	United Kingdom	1983
Study Group on the Effects of Bottom Trawling	P.A.M. Stewart	United Kingdom	1988
Study Group on Net Drawing	B. van Marlen	Netherlands	1988-1989
S.G. on Grid (Grate) Sorting Systems in Trawls, Beam Trawls and Seines	B. Isaksen	Norway	1995-1997
Sub-Group on Selectivity Methods	D. A. Wileman	Denmark	
Sub-Group on Survival Experiments	G. I. Sangster	United Kingdom	1992-1993
Study Group on Unaccounted Mortality in Fisheries	A. Frechet	Canada	1994-1997
S. G. on the Use of Selectivity and Effort Measurements in Stock Assessment	R..M. Cook & D. Somerton	United Kingdom United States	1997-1998
Study Group on the Selectivity of Static Gears	A. Carr	United States	1999-2001
Study Group on Mesh Measurement Methodology	R. Fonteyne	Belgium	2000-2001